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Reducing Threats to Ponderosa Pine Forests: Is Thinning Enough?

REDUCING THREATS TO PONDEROSA PINE FORESTS: IS THINNING ENOUGH?

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THE PROBLEM

Ponderosa pine forests are the focal point of a national discourse on declining forest health, increasing fire hazard, and the urban/wildland interface. Pine forests comprise the most extensive forest type in the Inland West, occupying over 27 million acres (Van Hooser and Keegan 1988). A century of logging, coupled with exclusion of historically frequent low-intensity fires, has resulted in dramatic changes in the density, structure, and species composition of these forests. In the Inland Northwest, many formerly open stands dominated by large pines have either been replaced by -- or filled in with -- late successional species such as Douglas-fir, grand fir, and/or white fir (Monnig and Byler 1992; Mutch et al. 1993; Arno et al. 1995).

Two widespread perceptions emerge from the debate on increased hazards in ponderosa pine forests: 1) it is a problem of too many small trees (Phillips 1995; Babbitt 1997), and 2) restoration treatments are expensive (Gorte 1994; Dombeck 1997). For example, if just 10 percent of national forest system lands in the western states -- 14 million acres -- were treated, total treatment costs would approach $3.5 billion (Gorte 1994).

Recently, officials in the U.S. Departments of Agriculture and Interior have recommended broadscale "restoration" treatments in ponderosa pine forests to reduce the risk of catastrophic fires, and associated threats to soil, water, wildlife, people,

and property. A much-recommended restoration approach consists of thinning small trees (low thinning), followed by prescribed underburning (Phillips 1995; Babbitt 1997; Dombeck 1997).

Our research since the mid-1980s has focused on developing a better understanding of the characteristics, structures, ecological processes, and management options in ponderosa pine forests, including distribution and volumes (Van Hooser and Keegan 1988), historical stand structures (Arno et al. 1995; 1996), fire history (Arno 1988), successional relationships (Arno et al. 1985), silvicultural methods (Fiedler et al. 1988; 1992), growth relationships (Fiedler 1995; Steele and Fiedler 1996), harvest costs and product values (Keegan et al. 1995), and initial restoration treatments (Fiedler et al. 1996; Arno 1996). Collectively, insights gained from this research lead us to question the efficacy of thin-from-below treatments for resolving the portentous ecological problems associated with these forests.

High stand densities, prevalence of sapling/pole understories, and a compositional shift to late seral species over millions of acres of pine forests serve to: 1) provide surface fires an avenue of entry into the overstory canopy, 2) increase susceptibility to pests, 3) preclude regeneration of shade-intolerant ponderosa pine, which is needed for this species to sustain (or regain) dominance, and 4) limit development of large-diameter pines, which are the characteristic structural feature in these stands and help ensure their sustainability.

The much-recommended thin-from-below treatment does little to alleviate high overall stand density or species conversion problems. Furthermore, this treatment is expensive, and is widely reported to require subtantial subsidy for operational level application (Gorte 1994; Dombeck 1997). Instead, a comprehensive restoration treatment is needed that addresses the full range of density, structural, and species compositional problems that characterize high hazard ponderosa pine stands, and threaten their sustainability.

APPROACH

In 1993, the Rocky Mountain Research Station, Bitterroot National Forest, and the University of Montana initiated a major collaborative research effort -- the Bitterroot Ecosystem Management Research Project. A primary objective of the overall Bitterroot Project is to develop and evaluate alternative management approaches for restoring altered Rocky Mountain ecosystems. In this paper, we report the results of an analysis of alternative restoration prescriptions (thin-from-below vs comprehensive) for an extensive high-hazard condition in the ponderosa pine forest type. Specific objectives of our analysis were to: 1) design a comprehensive ecological restoration prescription for degraded ponderosa pine stands, and 2) evaluate the potential for timber product values to offset treatment costs for both the thin-from-below and comprehensive restoration prescriptions.

We began our analysis by evaluating inventory records from over 500 stands on the Bitterroot National Forest. Our study focused on stands that differed significantly from historic conditions due to fire exclusion and past selective logging. Specifically, stands selected for analysis had: 1) basal area densities >100 ft^2/ac, and 2) understory (sapling/pole) densities >500 trees/ac. In contrast, pre-settlement pine stands averaged well below 100 ft^2/ac (Arno et al 1995; Habeck 1994; Covington and Moore 1994), and had few understory trees. If fires occur in stands with an understory tree layer (ladder fuel component), they can readily torch into the crowns of overstory trees and become stand replacement fires. If fire is excluded, the dense fir understories will eventually dominate the overstory as well, representing an even greater departure from historic conditions in terms of species composition and density (Arno et al. 1996). These conditions are broadly representative of Inland Northwest pine forests that have had fire excluded since the early 1900s (Agee 1993; Mutch et al. 1993; Phillips 1995).

The next step was to quantify the altered, high-hazard stand conditions in terms of density, structure, and species composition. We pooled the inventory data from the selected stands to create a composite stand table, which represents the average conditions in these stands in terms of trees per acre by species and diameter class. This stand table was then used to determine the numbers, sizes, and species of trees targeted for leave and cut under the thin-from-below and comprehensive

restoration prescriptions. It also provided the basis for determining the kinds and values of timber products associated with each prescription.

We then designed a comprehensive restoration prescription for the composite stand to reduce fire hazard by removing sapling- and pole-sized "ladder" fuels, promote regeneration of ponderosa pine by reducing overstory density, and increase the ratio of ponderosa pine to Douglas-fir/true firs by manipulating species composition throughout all size classes. This "consensus" prescription was critiqued and refined in collaboration with silviculturists and ecologists from the Forest Service, Bureau of Indian Affairs, State of Montana, and tribal forestry organizations.

TREATMENT PRESCRIPTIONS

Thin-from-below: The thin-from-below prescription is patterned after a number of proposed restoration projects in the Inland West. The upper diameter limit of trees to be harvested under this prescription is 9 in. Trees from 5 to 9 in. in diameter are removed and available for timber products; trees smaller than 5 in. are targeted to be cut and slashed.

Comprehensive Restoration Treatment

The comprehensive prescription includes three key components: 1) low thinning, in which trees <5 in. in diameter are cut and slashed, and trees 5 to 9 in. are removed and made available for products, 2) modified selection cutting, to reduce overstory density and induce regeneration of ponderosa pine,

helping to restore the uneven-aged structure that is characteristic of many historic stands (Weidman, 1921; Meyer, 1934; Arno et al. 1997), and 3) improvement cutting, to remove most Douglas-fir/true firs and trees of poor vigor or quality. Snags and live character trees are also left, as available. This prescription is implemented by leave-tree marking the best quality ponderosa pine (and up to 10 percent Douglas-fir) to a target reserve density of 40-60 ft^2/ac (Fiedler et al. 1988). Modestly higher densities can be kept in stands with a significant component of larger, older trees (Fiedler et al. 1997). Occasional small openings of 1/4- to 1/3-ac are created in the marking process to further encourage regeneration of ponderosa pine (Fiedler and Cully 1995).

TREATMENT REVENUES

Net revenues per acre were determined by subtracting harvest costs, haul costs, and costs of cutting and slashing trees <5 in. diameter, from the mill-delivered values of timber products associated with the number, size, and species of trees removed under each prescription. Not included in revenue calculations were the costs of subsequent treatments such as prescribed burning or spot planting.

We used an expert opinion approach to develop harvest costs, since neither of the two prescriptions was commonly used in the region. The composite stand table for the high-hazard conditions and the two restoration prescriptions were presented to logging

companies, who were then asked to bid on the harvest operations. Logging costs were estimated for typical harvest systems used on "tractor" ground (terrain with <35 percent slope), and on steeper terrain (≥35 percent slope, or "cable" ground).

We used diameter and species criteria to identify the timber products available from the trees targeted for removal under the alternative prescriptions. Mill-delivered product values were based on prices for the 1994-96 period (Bureau of Business and Economic Research 1997). Major timber products identified for the high-hazard pine/fir condition profiled in this paper include veneer logs, sawlogs, stud logs, and pulpwood. We estimated net revenues per acre with and without a roundwood pulpwood market, since this market fluctuates from strong to nonexistent as paper markets and lumber production vary (Keegan et al. 1995).

RESULTS AND DISCUSSION

Stand Conditions

The composite stand table shown in Table 1a represents average conditions in dense, late-successional ponderosa pine stands with a significant sapling/pole understory. The composite stand has an average basal area of 111 ft^2/acre, and about 575 trees per acre ≤9-inches in diameter breast height (DBH). Tables 1b and 1c portray stand conditions (trees per acre by diameter class and species) for the generic stand following application of the thin-from-below and the comprehensive restoration treatments, respectively.

The widely recommended thin-from-below prescription, followed by some form of slash treatment (prescribed burning or physical removal of slash from the site) is effective in reducing high-hazard fuels in stands with sapling- to pole-sized understories (Scott in press). It removes the ladder fuel component that allows surface fires a means to ascend into the main canopy. However, thinning-from-below reduces stand basal area by only about 25 percent, to 85 ft^2/acre, with virtually no reduction of density in the mid- and upper canopy. This treatment does not reduce overall stand density sufficiently to promote regeneration and early development of ponderosa pine, nor does it address the late successional component in the mid- to upper canopy, which remains as a continuing (and often unwanted) seed source. The relatively dense reserve stand, coupled with substantial amounts of slash fuels, also limits the application of prescribed burning.

The "consensus" restoration prescription, in contrast, is a comprehensive and strategic restoration approach aimed at creating a target reserve stand. This prescription manipulates tree density, structure, and species composition throughout the diameter distribution to *develop* and *sustain* desirable conditions based on historic structures and processes (i.e., more open forests featuring variable amounts of large ponderosa pines; Arno et al. 1996). Reserve tree densities are low enough to promote regeneration and early development of ponderosa pine (Fiedler et al. 1988), and enhance vigor and accelerate development of large-

diameter trees (Fiedler and Cully 1995). Sufficient small- and medium-sized pines are retained, to the extent available, to provide recruits for large trees in the future. The thin-from-below treatment, in contrast, does not reduce overall stand density enough to promote development of a large-tree component.

Revenues: Net revenues per acre varied, depending on: 1) the volume and kinds of products associated with the alternative prescriptions, 2) whether or not there was a pulpwood market, and 3) whether the high-hazard condition was on tractor or cable ground. The thin-from-below scenario had negative expected net revenue varying from -$120/ac on tractor ground with a roundwood/pulpwood market, to -$477/ac on cable ground without a pulpwood market (Table 2). In contrast, the comprehensive restoration treatment produced positive net revenues, varying from $877/ac on tractor ground with a pulpwood market, to $323/acre on cable ground without a pulpwood market (Table 2).

Direct comparison of alternative restoration approaches shows that the comprehensive prescription offers potential through the sale of timber products to generate substantial dollars ($323-$877/acre) to underwrite additional treatment costs, such as prescribed burning or spot planting. In contrast, the thin-from-below approach requires a subsidy just to remove the timber with some product value, much less to carry out desired follow-up restoration treatments.

CONCLUSIONS

The comprehensive treatment prescription differs from the "thin-from-below" approach to restoration in several important ways: 1) It addresses multiple aspects of the declining stand condition, not just the understory (ladder fuel) component, 2) it focuses on the reserve stand, sets density and composition targets, and achieves progress toward those targets, and 3) it opens the reserve stand sufficiently to allow effective follow-up application of prescribed burning.

Results of our economic evaluation challenge the perception that restoration treatments in pine/fir forests must come at a major cost to the taxpayer/landowner. In our study of high-hazard pine stands, restoration treatments aimed **solely** at ecological problems generated from $300 to nearly $900/ac, depending on terrain (tractor vs cable), and presence or absence of a pulpwood market. Indeed, the perception of restoration treatments as below cost becomes self-fulfilling if only the small-tree component of high-hazard stands is addressed. The difference between thinning-from-below and a comprehensive restoration treatment can be more than $1000/ac (Table 2), with the higher value prescription also better accomplishing ecological restoration goals.

Decisions on the kind and location of restoration treatments are made not only on stand-level ecological and economic factors, but also considering potential landscape-level effects and social issues. For example, the costly "thin-from-below" approach may

be the treatment of choice (at least initially) in recreation areas, campgrounds, or the wildland/urban interface. However, restoration of sustainable, large-pine dominated forests over significant areas of the western landscape cannot be accomplished either ecologically or economically through thin-from-below restoration approaches. Indeed, direct comparison of the two prescriptions shows that the comprehensive approach should be the prescription of choice, unless there are compelling reasons otherwise.

This does not imply that all dense ponderosa pine/fir stands should receive a comprehensive restoration treatment. Instead, in many areas it will be desirable to leave patches and stringers of uncut forest "marbled" through the landscape to meet management objectives for hiding cover, corridors for wildlife movement, and visual screening. Variations on the comprehensive restoration approach are also needed because management objectives vary, and because of the many differences in stands and how they might respond to treatment (Yazvenko and Rapport 1997). Where restoration of sustainable, pine-dominated forests is a primary objective, however, removal of ladder fuels, reduction in the proportion of firs, and reduction of stand density to promote regeneration and development of large pines will be essential treatment elements.

LITERATURE CITED

Agee, J.K. 1993. *Fire ecology of Pacific Northwest forests.* Covelo, CA: Island Press.

Arno, S.F., D.G. Simmerman, and R.E. Keane. 1985. *Forest succession on four habitat types in western Montana.* General Technical Report INT-177. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Arno, S.F. 1988. Fire ecology and its management implications in ponderosa pine forests. In *Ponderosa pine -- the species and its management,* comps. D.M. Baumgartner and J.E. Lotan, 133-140. Pullman, WA: Washington State University Cooperative Extension.

Arno, S.F., J.H. Scott, and M.G. Hartwell. 1995. *Age-class structure of old-growth ponderosa pine/Douglas-fir stands and its relationship to fire history.* Research Paper INT-RP-481. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Arno, S.F., M.G. Harrington, C.E. Fiedler, and C.E. Carlson. 1996. Using silviculture and prescribed fire to reduce fire hazard and improve health in ponderosa pine forests. In *Proceedings Seventeenth Annual Forest Vegetation Management Conference,* 114-118. Redding, CA: Forest Vegetation Management Conference.

Arno, S.F., H.Y. Smith, and M.A. Krebs. 1997. *Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fires and fire exclusion.* Research Paper INT-RP-495. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Babbitt, B. 1997. *A coordinated campaign: fight fire with fire.* Text of speech delivered at Boise State University, Boise, ID.

Bureau of Business and Economic Research. 1997. *Log price reporting system.* Missoula, MT: University of Montana.

Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure changes since Euro-American settlement. *Journal of Forestry* 92:39-47.

Dombeck, M. 1997. Text of statement to Senate Committee on Energy and Natural Resources. Washington, D.C.: United States Senate.

Fiedler, C.E., R.R. Becker, and S.A. Haglund. 1988. Preliminary guidelines for uneven-aged silvicultural prescriptions in ponderosa pine. In *Ponderosa pine -- the species and its management,* comps. D.M. Baumgartner and J.E. Lotan, 235-241. Pullman, WA: Washington State University Cooperative Extension.

Fiedler, C.E. 1995. The basal area-maximum diameter-q (BDq) approach to regulating uneven-aged stands. In *Uneven-aged Management: Opportunities, Constraints and Methodologies,* ed. K.L. O'Hara, 94-109. MFCES Miscellaneous publication No. 56. Missoula, MT: Montana Forest and Conservation Experiment Station.

Fiedler, C.E., and J.F. Cully. 1995. A silvicultural approach to develop Mexican spotted owl habitat in Southwest forests. *Western Journal of Applied Forestry* 10:144-148.

Fiedler, C.E., S.F. Arno, and M.G. Harrington. 1996. Flexible silvicultural and prescribed burning approaches for improving health of ponderosa pine forests. In *Conference on Adaptive Ecosystem Restoration and Management: Restoration of Cordilleran Conifer Landscapes of North America,* tech. coords. W. Covington and P.K. Wagner, 69-74. General Technical Report RM-GTR-278. Ft. Collins, CO: USDA Forest Service Rocky Mountain Forest and Range Experiment Station.

Fiedler, C.E., S.F. Arno, and M.G. Harrington. 1997. *Reintroducing fire in ponderosa pine-fir forests after a century of fire exclusion.* Tall Timbers Fire Ecology Conference Proceedings 20:000-000. In press.

Fiedler, C.E., S.F. Arno, C.E. Carlson, and M.G. Harrington. 1992. Management prescriptions for restoring biodiversity in Inland Northwest pine-fir forests. *Northwest Environmental Journal* 8:211-213.

Gorte, R.W. 1994. *Forest fires and forest health activities*. Memo to G. Miller, House Committee on Natural Resources. Congressional Research Service. Washington, DC: Library of Congress.

Habeck, J.R. 1994. Using General Land Office records to assess forest succession in ponderosa pine/Douglas-fir forests in western Montana. *Northwest Science* 68:69-78.

Keegan, C.E., D.P. Wichman, A.L. Hearst, P.E. Polzin, and D.D. Van Hooser. 1995. *Montana forest products industry: a descriptive analysis*. Bureau of Business and Economic Research. Missoula, MT: University of Montana.

Meyer, W.H. 1934. *Growth in selectively cut ponderosa pine forests of the Pacific Northwest*. USDA Technical Bulletin No. 407. Washington, D.C.: United States Department of Agriculture.

Monnig, E., and J. Byler. 1992. *Forest health and ecological integrity in the Northern Rockies*. FPM Report 92-7. Missoula, MT: USDA Forest Service Northern Region.

Mutch, R.W., S.F. Arno, J.K. Brown, C.E. Carlson, R.D. Ottmar, and J.L. Peterson. 1993. *Forest health in the Blue Mountains: A management strategy for fire adapted ecosystems*. General Technical Report PNW-GTR-310. Portland, OR: USDA Forest Service Pacific Northwest Research Station.

Phillips, J. 1995. The crisis in our forests. *Sunset* July:87-92.

Scott, J.H. 1998. *Fuel reduction in residential and scenic forests: a comparison of three treatments in a western Montana ponderosa pine stand*. Research Paper RM-RP-000 (in press). Ogden, UT: USDA Forest Service Rocky Mountain Research Station.

Steele, B.M., and C.E. Fiedler. 1996. Kalman filter analysis of growth-climate relationships in old-growth ponderosa pine/Douglas-fir stands. *Radiocarbon* 1996:303-314.

Van Hooser, D., and C.E. Keegan. 1988. Distribution and volumes of ponderosa pine forests. In *Ponderosa pine -- the species and its management,* comps. D.M. Baumgartner and J.E. Lotan, 1-6. Pullman, WA: Washington State University Cooperative Extension.

Weidman, R.H. 1921. Forest succession as the basis of the silviculture of western yellow pine. *Journal of Forestry* 19:877-885.

Yazvenko, S.B., and D.J. Rapport. 1997. The history of ponderosa pine pathology: Implications for management. *Journal of Forestry* 95:16-20.

ABSTRACT Dramatic post-1900 changes in the density, structure, and species composition of western ponderosa pine forests threaten their sustainability. Thinning-from-below -- a widely-proposed restoration treatment -- does not address the full range of problems associated with these altered stand conditions. We propose a comprehensive restoration approach to induce pine regeneration, develop and sustain large-diameter pine, reduce composition of late-seral species, and manipulate structure to reduce fire hazard and allow use of prescribed fire. Our analysis indicates that thinning-from-below does not accomplish these goals, and requires subsidies ranging from $120 to nearly $475/ac. The comprehensive approach, in contrast, moves existing stands more rapidly toward ecologically desirable and sustainable conditions, while generating positive revenues of $320 to $875/ac from timber products.

Table 1. Composite stand table: a) representing average conditions in dense ponderosa pine/fir stands with a significant understory component, b) following application of a thin-from-below treatment, and c) following application of a comprehensive restoration treatment.

a)

DBH class -(in)-	Ponderosa pine (TPA)	Douglas-fir/ true firs (TPA)	All species (TPA)
0.1-4.9	44	459	503
5.0-9.9	17	54	71
10.0-14.9	22	14	36
15.0-19.9	14	8	22
≥20.0	6	0	6

b)

DBH class -(in)-	Ponderosa pine (TPA)		Douglas-fir/ true firs (TPA)		All species (TPA)	
	Leave	Cut	Leave	Cut	Leave	Cut
0.1-4.9	0	44[1/]	0	459	0	503
5.0-9.9	0	17[2/]	0	54	0	71
10.0-14.9	22	0	14	0	36	0
15.0-19.9	14	0	8	0	22	0
≥20.0	6	0	0	0	6	0

c)

DBH class -(in)-	Ponderosa pine (TPA)		Douglas-fir/ true firs (TPA)		All species (TPA)	
	Leave	Cut	Leave	Cut	Leave	Cut
0.1-4.9	0	44[1/]	0	459	0	503
5.0-9.9	12	5[2/]	0	54	12	59
10.0-14.9	10	12	0	14	10	26
15.0-19.9	14	0	0	8	14	8
≥20.0	6	0	0	0	6	0

[1/] Trees 0 to 4.9 in. are treated in a variety of ways, depending on ownership, terrain, and management objectives. Small trees may be cut, slashed, and left in the woods, or cut and removed from the woods. Alternatively, only about 1/4 to 1/3 of the <5-in. trees may be cut, with the resulting slash serving to carry a follow-up prescribed underburn aimed at killing most of the remaining small trees.

[2/] Trees 5.0 to 9.9 in. are cut, removed from the woods, and available for timber products.

Table 2. Net revenues (dollars/acre) associated with alternative restoration prescriptions and harvest systems in high-hazard ponderosa pine/fir stands.

Prescription	Tractor with Pulpwood	Tractor w/o Pulpwood	Cable with Pulpwood	Cable w/o Pulpwood
Thin-from-below	$-120	-211	-386	-477
Comprehensive	877	807	394	323
Difference	997	1018	780	800

Figure 1. Visualizations of: a) existing conditions in dense ponderosa pine/fir stands with a significant understory component, b) conditions following application of a thin-from-below treatment, and c) conditions following application of a comprehensive restoration treatment.

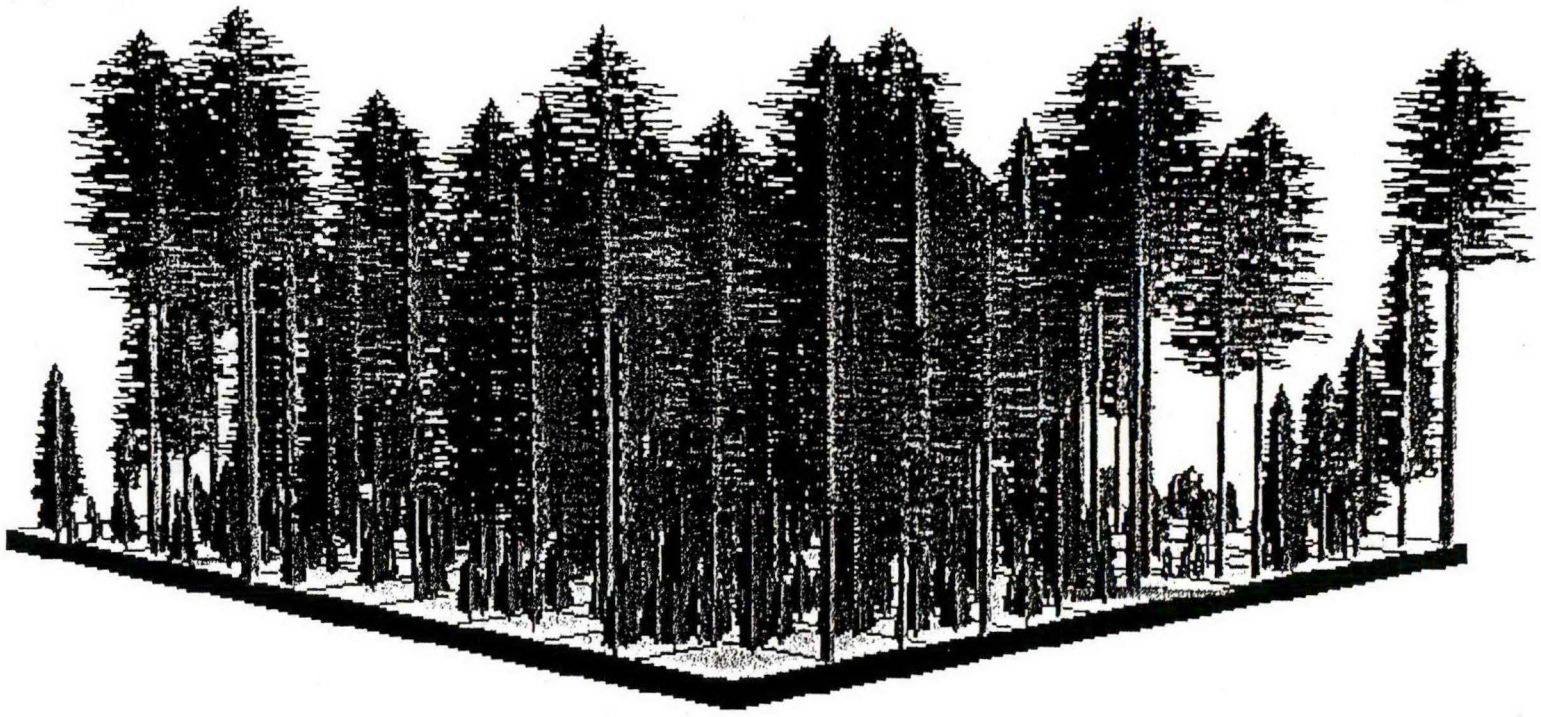

Figure 1a.

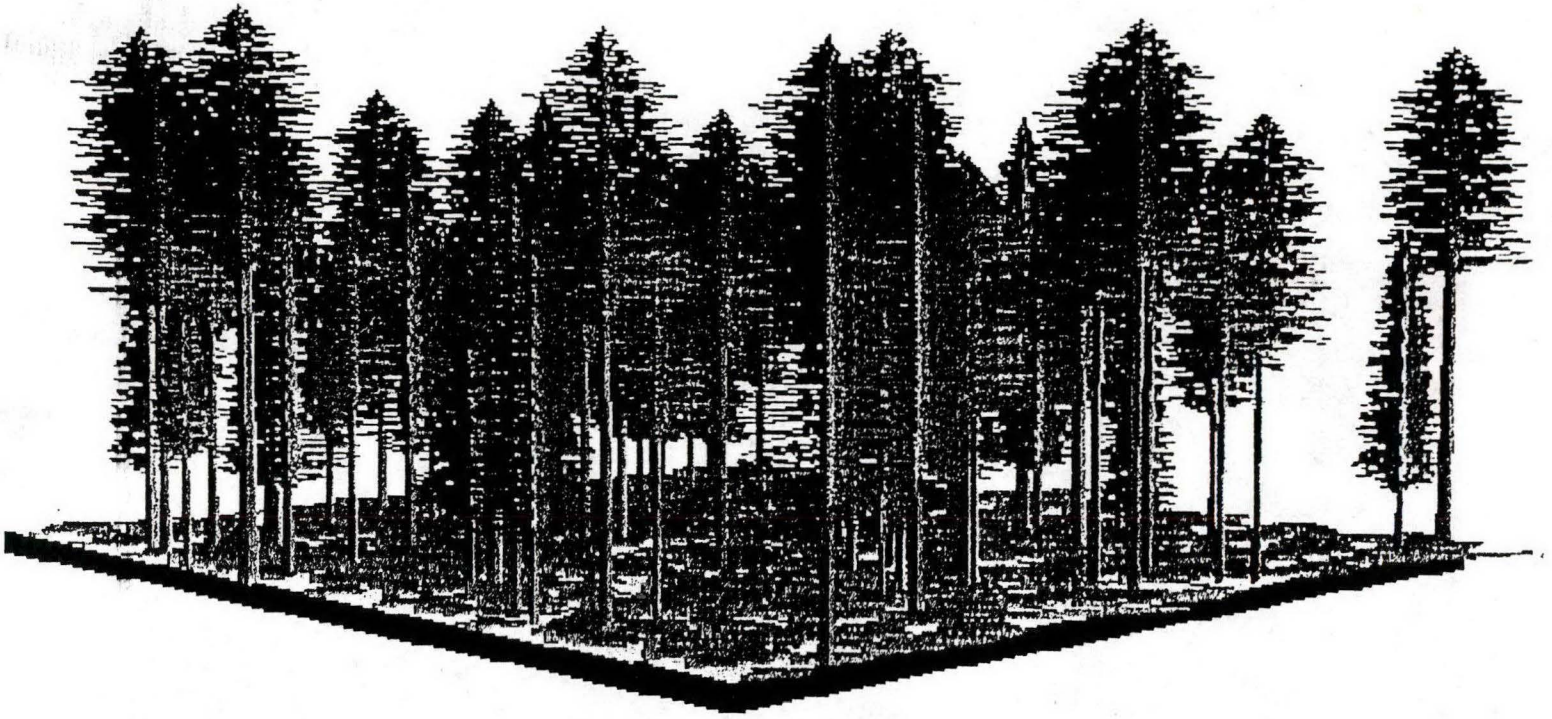

Figure 1b.

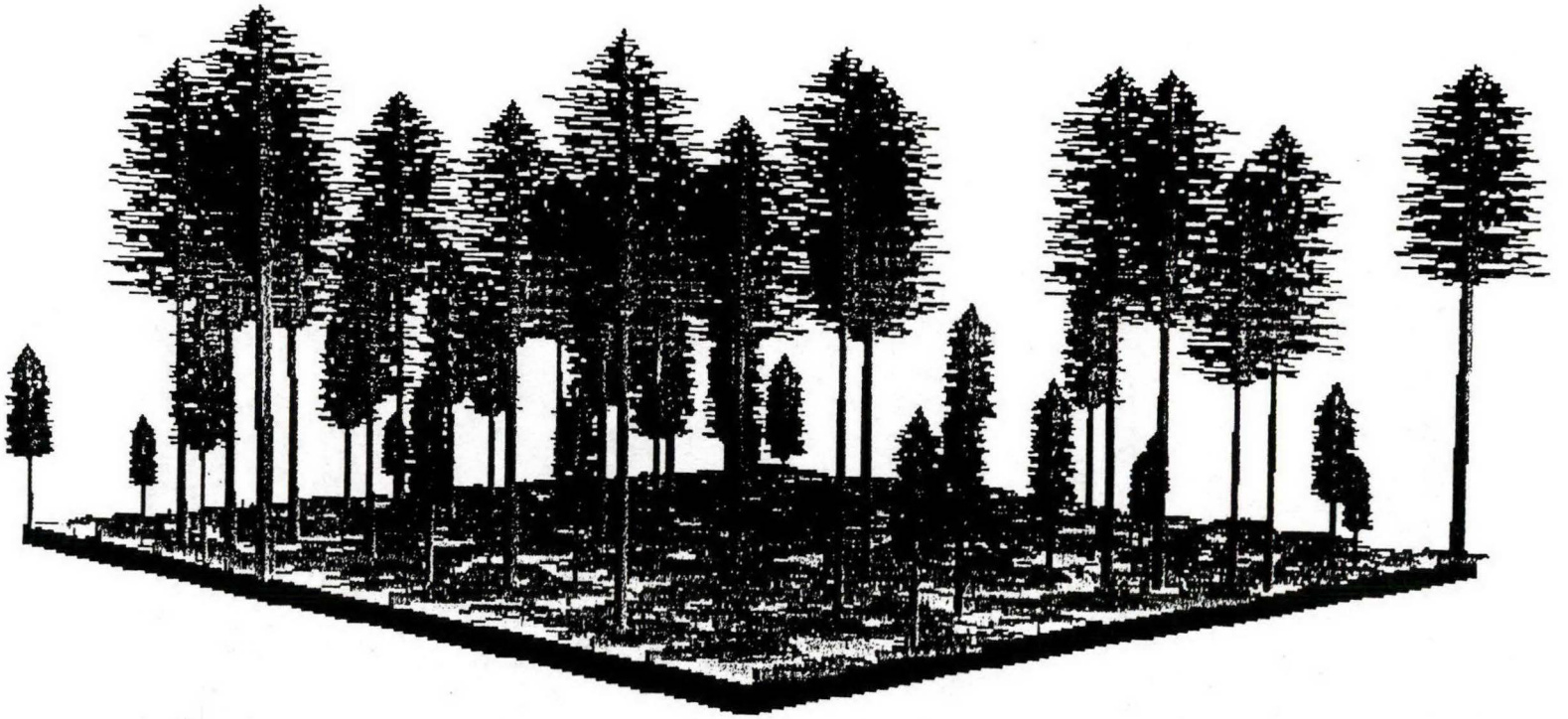

Figure 1c.